In situ X-ray imaging of solidification and deformation mechanisms in Fe based alloys

Highlights

- Advanced techniques – in situ observation of phase transformations using diffraction and real-space imaging
- Advanced alloys with both applied and fundamental materials/mechanical engineering problems – the optimisation of alloys that will be achieved as part of this investigation in select few advanced Fe based alloys is posited to have strong impact on automotive and renewable energy sector
- Student support and industrial exposure - The studentship will be supported by three post-doctoral researchers, two based Technical University of Denmark (DTU) and one at the UK’s X-ray synchrotron facility, Harwell Campus, Oxfordshire. The proposed project has a strong industrial collaboration network, including with Sidenor Steel, Fiat, Siemens, Vestas and MAN Energy Solutions, recently established via recently two European grants

Overview

Iron based structural alloys are crucial for almost all industrial sectors, including automotive, maritime through to production of wind powered turbines. The thermo-mechanical processing pathways adopted for Fe alloys used in these applications are in majority of the cases established empirically, and several aspects of very high temperature (just below solidus) deformation has not been fully understood. For example, there is lack of understanding of the:

- Kinetics of phase transformations, especially the nucleation and growth dynamics
- Influence of the evolution of phases on the high temperature deformation behaviour.
- Impact of phase evolution and deformation on final properties.

(a)-(d) 4D (3D + time) observation of formation and evolution of nodular and degenerated nodular graphite phase during solidification of a cast iron alloy. Three degenerated nodules, N1 (red), N2 (blue) and N3 (green) have been emphasized to demonstrate the various stages involved in the development of degenerated features. Initially, the nodules assume a spherical morphology, as shown in (a). Then, the degenerated features start to appear via formation of polyps, as indicated by red arrows in (b). On the ends of the polyps, more features develop during later stages of solidification, as shown in (c) and (d). The two mechanisms of formation of degenerated morphologies are schematically shown in (e) and (f) respectively. The morphology of bead-like growth in nodule N3 examined at room temperature using an optical microscope is shown in (g). Scale bar = 50 µm.
The objectives of the proposed project are to perform experiments and analyses to investigate 1 and 2. The prospective student will use in situ X-ray imaging and diffraction to capture and analyse the microstructure evolution in Fe based FCC austenitic alloys at high temperature (just below solidus). These investigations will be performed on different types of alloys, interstitial (Fe-C base alloys) and microalloyed (Fe-X (X=Nb, Ti, V, Mo, Zr) steels.

In first part of this project, the student will identify a select few compositions from the different alloy classes, where the resulting microstructure will be single phase solid solution. The alloys will be either supplied by one of our industrial partners or us and they will be hot rolled to achieve a refined grain size (~30 µm).

The investigation will be performed using simultaneous in situ high temperature X-ray imaging+diffraction investigation on the manufactured alloys to capture the kinetics of phase evolution, lattice strains, dislocation density, and texture evolution at high temperature. You will first image microstructure evolution during solidification process of iron-C alloys, then using diffraction determine the effect of phase evolution on strain and cracking behaviour.

Methodology
The alloys used in this investigation will be manufactured by vacuum arc melting process and hot rolled to refine the grain size to ~30 µm. The refined grain size is essential to obtain complete Debye-Scherrer rings for lattice strain measurements and complete quantitative microstructure analysis during high temperature in situ simultaneous imaging and diffraction experiments. Tensile flat or round dog bone shape sample will be used and the high temperature deformation will be performed in a bespoke set up; a high temperature environmental cell which can up to 1550 °C and a servo hydraulic tensile testing machine. The environmental cell has a customizable window for simultaneously capturing imaging and diffraction data.

The in situ experiments will be performed using X-ray instruments at various synchrotron facilities, in UK and worldwide. Typically 2 synchrotron beamtimes are required to obtain enough data for fully delivering on the proposed project.

Further Reading
Funding
This research project is one of a number of projects in the Department. It is in competition for funding with one or more of these projects. Usually the project which receives the best applicant will be awarded the funding.

Home/EU Applicants
This project is eligible for a fully funded College of Science and Engineering studentship which includes:

- A full UK/EU fee waiver for 3.5 years
- An annual tax free stipend of £14,777 (2018/19)
- Research Training Support Grant (RTSG)

International Applicants
This project is eligible for a fully funded College of Science and Engineering studentship which includes:

- A full international fee waiver for 3.5 years
- Research Training Support Grant (RTSG)

Application Instructions
The online application and supporting documents are due by Monday 21st January 2019.

Any applications submitted after the deadline will not be accepted for the studentship scheme.

References should arrive no later than Monday 28th January 2019.

Applicants are advised to apply well in advance of the deadline, so that we can let you know if anything is missing from your application.

Required Materials
1. Online application form
2. Two academic references
3. Transcripts
4. Degree certificate/s (if awarded)
5. Curriculum Vitae
6. CSE Studentship Form
7. English language qualification

Applications which are not complete by the deadline will not be considered for the studentship scheme. It is the responsibility of the applicant to ensure the application form and documents are received by the relevant deadlines.
All applications must be submitted online, along with the supporting documents as per the instructions on the website.

Please ensure that all email addresses, for yourself and your referees, are correct on the application form.

For more information, please visit our website at:

https://www2.le.ac.uk/colleges/scieng/research/postgraduate-opportunities/cse-2019/instructions